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(54) Title: CYANO COMPOUNDS (57) Abstract Novel compounds are described herein. These compounds inhibit the production of Tumor Necrosis Factor and are useful in the treatment of disease states mediated or exacerbated by TNF production; these compounds are also useful in the mediation or inhibition of enzymatic or catalytic activity of phosphodiesterase IV.		

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CYANO COMPOUNDS

Field of Invention

The present invention relates to novel compounds, pharmaceutical compositions containing these compounds, and their use in treating allergic and inflammatory diseases and for inhibiting the production of Tumor Necrosis Factor (TNF).

Background of the Invention

Bronchial asthma is a complex, multifactorial disease characterized by reversible narrowing of the airway and hyperreactivity of the respiratory tract to external stimuli.

Identification of novel therapeutic agents for asthma is made difficult by the fact that multiple mediators are responsible for the development of the disease. Thus, it seems unlikely that eliminating the effects of a single mediator will have a substantial effect on all three components of chronic asthma. An alternative to the "mediator approach" is to regulate the activity of the cells responsible for the pathophysiology of the disease.

One such way is by elevating levels of cAMP (adenosine cyclic 3',5'-monophosphate). Cyclic AMP has been shown to be a second messenger mediating the biologic responses to a wide range of hormones, neurotransmitters and drugs; [Krebs Endocrinology Proceedings of the 4th International Congress Excerpta Medica, 17-29, 1973]. When the appropriate agonist binds to specific cell surface receptors, adenylate cyclase is activated, which converts Mg^{+2} -ATP to cAMP at an accelerated rate.

Cyclic AMP modulates the activity of most, if not all, of the cells that contribute to the pathophysiology of extrinsic (allergic) asthma. As such, an elevation of cAMP would produce beneficial effects including: 1) airway smooth muscle relaxation, 2) inhibition of mast cell mediator release, 3) suppression of neutrophil degranulation, 4) inhibition of basophil degranulation, and 5) inhibition of monocyte and macrophage activation. Hence, compounds that activate adenylate cyclase or inhibit phosphodiesterase should be effective in suppressing the inappropriate activation of airway smooth muscle and a wide variety of inflammatory cells. The principal cellular mechanism for the inactivation of cAMP is hydrolysis of the 3'-phosphodiester bond by one or more of a family of isozymes referred to as cyclic nucleotide phosphodiesterases (PDEs).

It has now been shown that a distinct cyclic nucleotide phosphodiesterase (PDE) isozyme, PDE IV, is responsible for cAMP breakdown in airway smooth muscle and inflammatory cells. [Torphy, "Phosphodiesterase Isozymes: Potential
5 Targets for Novel Anti-asthmatic Agents" in New Drugs for Asthma, Barnes, ed. IBC Technical Services Ltd., 1989]. Research indicates that inhibition of this enzyme not only produces airway smooth muscle relaxation, but also suppresses degranulation of mast cells, basophils and neutrophils along with inhibiting the activation of monocytes and neutrophils. Moreover, the beneficial effects of PDE
10 IV inhibitors are markedly potentiated when adenylate cyclase activity of target cells is elevated by appropriate hormones or autocoids, as would be the case *in vivo*. Thus PDE IV inhibitors would be effective in the asthmatic lung, where levels of prostaglandin E₂ and prostacyclin (activators of adenylate cyclase) are elevated. Such compounds would offer a unique approach toward the pharmacotherapy of
15 bronchial asthma and possess significant therapeutic advantages over agents currently on the market.

The compounds of this invention also inhibit the production of Tumor Necrosis Factor (TNF), a serum glycoprotein. Excessive or unregulated TNF production has been implicated in mediating or exacerbating a number of diseases
20 including rheumatoid arthritis, rheumatoid spondylitis, osteoarthritis, gouty arthritis and other arthritic conditions; sepsis, septic shock, endotoxic shock, gram negative sepsis, toxic shock syndrome, adult respiratory distress syndrome, cerebral malaria, chronic pulmonary inflammatory disease, silicosis, pulmonary sarcoidosis, bone resorption diseases, reperfusion injury, graft vs. host reaction, allograft rejections,
25 fever and myalgias due to infection, such as influenza, cachexia secondary to infection or malignancy, cachexia secondary to human acquired immune deficiency syndrome (AIDS), AIDS, ARC (AIDS related complex), keloid formation, scar tissue formation, Crohn's disease, ulcerative colitis, or pyresis, in addition to a number of autoimmune diseases, such as multiple sclerosis, autoimmune diabetes
30 and systemic lupus erythematosus.

AIDS results from the infection of T lymphocytes with Human Immunodeficiency Virus (HIV). At least three types or strains of HIV have been identified, i.e., HIV-1, HIV-2 and HIV-3. As a consequence of HIV infection, T-cell-mediated immunity is impaired and infected individuals manifest severe
35 opportunistic infections and/or unusual neoplasms. HIV entry into the T lymphocyte requires T lymphocyte activation. Viruses such as HIV-1 or HIV-2 infect T lymphocytes after T cell activation and such virus protein expression and/or

replication is mediated or maintained by such T cell activation. Once an activated T lymphocyte is infected with HIV, the T lymphocyte must continue to be maintained in an activated state to permit HIV gene expression and/or HIV replication.

5 Cytokines, specifically TNF, are implicated in activated T-cell-mediated HIV protein expression and/or virus replication by playing a role in maintaining T lymphocyte activation. Therefore, interference with cytokine activity such as by inhibition of cytokine production, notably TNF, in an HIV-infected individual aids in limiting the maintenance of T cell activation, thereby reducing the progression of HIV infectivity to previously uninfected cells which results in a slowing or
10 elimination of the progression of immune dysfunction caused by HIV infection. Monocytes, macrophages, and related cells, such as kupffer and glial cells, have also been implicated in maintenance of the HIV infection. These cells, like T cells, are targets for viral replication and the level of viral replication is dependent upon the activation state of the cells. [See Rosenberg *et al.*, The Immunopathogenesis of
15 HIV Infection, Advances in Immunology, Vol. 57, 1989]. Monokines, such as TNF, have been shown to activate HIV replication in monocytes and/or macrophages [See Poli *et al.*, Proc. Natl. Acad. Sci., 87:782-784, 1990], therefore, inhibition of monokine production or activity aids in limiting HIV progression as stated above for T cells.
20 TNF has also been implicated in various roles with other viral infections, such as the cytomegalovirus (CMV), influenza virus, adenovirus, and the herpes virus for similar reasons as those noted.

TNF is also associated with yeast and fungal infections. Specifically *Candida albicans* has been shown to induce TNF production *in vitro* in human
25 monocytes and natural killer cells. [See Riipi *et al.*, Infection and Immunity, 58(9):2750-54, 1990; and Jafari *et al.*, Journal of Infectious Diseases, 164:389-95, 1991. See also Wasan *et al.*, Antimicrobial Agents and Chemotherapy, 35,(10):2046-48, 1991; and Luke *et al.*, Journal of Infectious Diseases, 162:211-214, 1990].

30 The ability to control the adverse effects of TNF is furthered by the use of the compounds which inhibit TNF in mammals who are in need of such use. There remains a need for compounds which are useful in treating TNF-mediated disease states which are exacerbated or caused by the excessive and/or unregulated production of TNF.

35 **Summary of the Invention**

This invention relates to the novel compounds of Formulas (I) and (II) as shown below, useful in the mediation or inhibition of the enzymatic activity (or

catalytic activity) of phosphodiesterase IV (PDE IV). These compounds also have Tumor Necrosis Factor (TNF) inhibitory activity.

5 This invention also relates to the pharmaceutical compositions comprising a compound of Formulas (I) or (II) and a pharmaceutically acceptable carrier or diluent.

The invention also relates to a method of mediation or inhibition of the enzymatic activity (or catalytic activity) of PDE IV in mammals, including humans, which comprises administering to a mammal in need thereof an effective amount of a compound of Formula (I) or (II) as shown below.

10 The invention further provides a method for the treatment of allergic and inflammatory disease which comprises administering to a mammal, including humans, in need thereof, an effective amount of a compound of Formula (I) or (II).

The invention also provides a method for the treatment of asthma which comprises administering to a mammal, including humans, in need thereof, an effective amount of a compound of Formula (I) or (II).

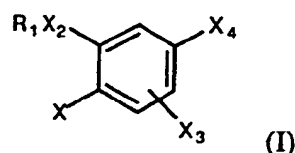
15 This invention also relates to a method of inhibiting TNF production in a mammal, including humans, which method comprises administering to a mammal in need of such treatment, an effective TNF inhibiting amount of a compound of Formula (I) or (II). This method may be used for the prophylactic treatment or prevention of certain TNF mediated disease states amenable thereto.

This invention also relates to a method of treating a human afflicted with a human immunodeficiency virus (HIV), which comprises administering to such human an effective TNF inhibiting amount of a compound of Formula (I) or (II).

20 Compounds of Formula (I) or (II) are also useful in the treatment of additional viral infections, where such viruses are sensitive to upregulation by TNF or will elicit TNF production *in vivo*.

25 In addition, compounds of Formula (I) or (II) are also useful in treating yeast and fungal infections, where such yeast and fungi are sensitive to upregulation by TNF or will elicit TNF production *in vivo*.

The compounds of Formula (I) are represented by the following structure:



5 wherein:

R_1 is $-(CR_4R_5)_nC(O)O(CR_4R_5)_mR_6$, $-(CR_4R_5)_nC(O)NR_4(CR_4R_5)_mR_6$, $-(CR_4R_5)_nO(CR_4R_5)_mR_6$, or $-(CR_4R_5)_rR_6$ wherein the alkyl moieties may be optionally substituted with one or more halogens;

m is 0 to 2;

10 n is 1 to 4;

r is 0 to 6;

R_4 and R_5 are independently selected from hydrogen or a C_{1-2} alkyl;

R_6 is hydrogen, methyl, hydroxyl, aryl, halo substituted aryl, aryloxy C_{1-3} alkyl, halo substituted aryloxy C_{1-3} alkyl, indanyl, indenyl, C_{7-11} polycycloalkyl, tetrahydrofuranyl, furanyl, tetrahydropyranyl, pyranal, tetrahydrothienyl, thienyl, tetrahydrothiopyranal, thiopyranal, C_{3-6} cycloalkyl, or a C_{4-6} cycloalkyl containing one or two unsaturated bonds, wherein the cycloalkyl and heterocyclic moieties may be optionally substituted by 1 to 3 methyl groups or one ethyl group;

provided that:

20 a) when R_6 is hydroxyl, then m is 2; or

b) when R_6 is hydroxyl, then r is 2 to 6; or

c) when R_6 is 2-tetrahydropyranyl, 2-tetrahydrothiopyranal, 2-tetrahydrofuranyl, or 2-tetrahydrothienyl, then m is 1 or 2; or

d) when R_6 is 2-tetrahydropyranyl, 2-tetrahydrothiopyranal, 2-tetrahydrofuranyl, or 2-tetrahydrothienyl, then r is 1 to 6;

25 e) when n is 1 and m is 0, then R_6 is other than H in $-(CR_4R_5)_nO(CR_4R_5)_mR_6$;

X is YR_2 , halogen, nitro, NR_4R_5 , or formyl amine;

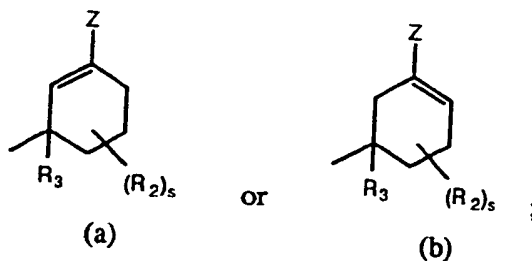
Y is O or $S(O)_{m'}$;

30 m' is 0, 1, or 2;

X_2 is O or NR_8 ;

X_3 is hydrogen or X;

X₄ is



5 R₂ is independently selected from -CH₃ or -CH₂CH₃ optionally substituted by 1 or more halogens;

s is 0 to 4;

R₃ is C₁₋₄ alkyl, fluoro-substituted C₁₋₄ alkyl, CH₂NHC(O)C(O)NH₂, -CH=CR₈R₈', cyclopropyl optionally substituted by R₈', CN, CH₂OR₈,
10 CH₂NR₈R₁₀, C(Z')H, C(O)OR₈, C(O)NR₈R₁₀, or C≡CR₈;

Z is S(O)_mR₉, OS(O)₂R₉, OR₉, OC(O)NR₇R₉, OC(O)(O)_qR₇, O(CR₄R₅)_nOR₉, or NR₉R₉;

Z' is O, NR₈, NNR₈R₈, NOR₈, NCN, C(-CN)₂, CR₈CN, CR₈NO₂, CR₈C(O)OR₈, CR₈C(O)NR₈R₈, C(-CN)NO₂, C(-CN)C(O)OR₉, or
15 C(-CN)C(O)NR₈R₈;

q is 0 or 1;

R₇ is independently hydrogen or R₉;

R₈ is independently selected from hydrogen or C₁₋₄ alkyl optionally substituted by one to three fluorines, or when R₈ and R₁₀ are as -NR₈R₁₀ they may
20 together with the nitrogen form a 5 to 7 membered ring optionally containing one or more additional heteroatom selected from O, N, or S;

R₈' is R₈ or fluorine;

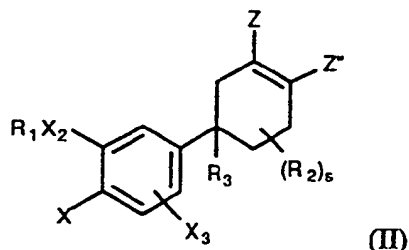
R₉ is independently C₁₋₁₀ alkyl, C₂₋₁₀ alkenyl, C₃₋₇cycloalkyl, C₄₋₆ cycloalkenyl, aryl, arylalkyl, heteroaryl, heteroarylalkyl, each of which may be
25 optionally substituted by one or more fluorine atoms, or two R₉ terms appearing as NR₉R₉ may together with the nitrogen form a 5 to 7 membered ring optionally containing one or more additional heteroatoms selected from O, N, or S;

R₁₀ is OR₈ or R₈;

provided that:

30 f) when q is 1 in OC(O)(O)_qR₇, then R₇ is not hydrogen;
g) when Z' is NR₈, then R₈ is not hydrogen;
or the pharmaceutically acceptable salts thereof.

The other set of compounds of this invention are represented by Formula (II):



wherein the several groups are the same as those of Formula (I) and:

5 Z is also NHR_{14} ;

Z' is $\text{C(Y')}R_{14}$, C(O)OR_{14} , $\text{C(Y')NR}_{10}R_{14}$, $\text{C(NR}_{10})\text{NR}_{10}R_{14}$, CN, $\text{C(NOR}_8)R_{14}$, $\text{C(NOR}_{14})R_8$, $\text{C(NR}_8)\text{NR}_{10}R_{14}$, $\text{C(NR}_{14})\text{NR}_8R_8$, $\text{C(NCN)NR}_{10}R_{14}$, C(NCN)SR_{11} , (2-, 4- or 5-imidazolyl), (3-, 4- or 5-pyrazolyl), (4- or 5-triazolyl[1,2,3]), (3- or 5-triazolyl[1,2,4]), (5-tetrazolyl), (2-, 4- or
10 5-oxazolyl), (3-, 4- or 5-isoxazolyl), (3- or 5-oxadiazolyl[1,2,4]), (2-oxadiazolyl[1,3,4]), (2-thiadiazolyl[1,3,4]), (2-, 4-, or 5-thiazolyl), (2-, 4-, or 5-oxazolidinyl), (2-, 4-, or 5-thiazolidinyl), or (2-, 4-, or 5-imidazolidinyl); wherein all of the heterocyclic ring systems may be optionally substituted one or more times by R_{14} ;

15 Y' is O or S;

R_{11} is C_{1-4} alkyl optionally substituted by one to three fluorines;

R_{12} is C_{3-7} cycloalkyl, (2-, 3- or 4-pyridyl), pyrimidyl, pyrazolyl, (1- or 2-imidazolyl), thiazolyl, triazolyl, pyrrolyl, piperaziny, piperidinyl, morpholinyl, furanyl, (2- or 3-thienyl), (4- or 5-thiazolyl), quinolinyl, naphthyl, or phenyl;

20 R_{13} is oxazolidinyl, oxazolyl, thiazolyl, pyrazolyl, triazolyl, tetrazolyl, imidazolyl, imidazolidinyl, thiazolidinyl, isoxazolyl, oxadiazolyl, or thiadiazolyl, and each of these heterocyclic rings is connected through a carbon atom and each may be unsubstituted or substituted by one or two C_{1-2} alkyl groups;

R_{14} is hydrogen or R_{15} ; or when R_{10} and R_{14} are as $\text{NR}_{10}R_{14}$ they may
25 together with the nitrogen form a 5 to 7 membered ring optionally containing one or more additional heteroatoms selected from O/N/or S;

R_{15} is $-(\text{CR}_4\text{R}_5)_tR_{12}$ or C_{1-6} alkyl wherein the R_{12} or C_{1-6} alkyl group is optionally substituted one or more times by C_{1-2} alkyl optionally substituted by one to three fluorines, -F, -Br, -Cl, - NO_2 , - $\text{Si(R}_4)_2$, - NR_8R_{10} , - C(O)R_8 , - C(O)OR_8 , -
30 OR_8 , -CN, - C(O)NR_8R_{10} , - OC(O)NR_8R_{10} , - OC(O)R_8 , - $\text{NR}_{10}\text{C(O)NR}_8R_{10}$, - $\text{NR}_{10}\text{C(O)R}_8$, - $\text{NR}_{10}\text{C(O)OR}_9$, - $\text{NR}_{10}\text{C(O)R}_{13}$, - $\text{C(NR}_{10})\text{NR}_8R_{10}$, - C(NCN)NR_8R_{10} , - C(NCN)SR_{11} , - $\text{NR}_{10}\text{C(NCN)SR}_{11}$, - $\text{NR}_{10}\text{C(NCN)NR}_{10}R_8$,

-NR₁₀S(O)₂R₉, -S(O)_mR₁₁, -NR₁₀C(O)C(O)NR₈R₁₀, -NR₁₀C(O)C(O)R₁₀,
thiazolyl, imidazolyl, oxazolyl, pyrazolyl, triazolyl, or tetrazolyl;

t is 0, 1, or 2;

provided that when R₁₂ is N-pyrazolyl, N-imidazolyl, N-triazolyl, N-
5 pyrrolyl, N-piperaziny, N-piperidinyl, or N-morpholinyl, then q is not 1;
or a pharmaceutically acceptable salts thereof.

Detailed Description of the Invention

This invention also relates to a method of mediating or inhibiting the
enzymatic activity (or catalytic activity) of PDE IV in a mammal in need thereof
10 and to inhibiting the production of TNF in a mammal in need thereof, which
comprises administering to said mammal an effective amount of a compound of
Formula (I) or (II).

Phosphodiesterase IV inhibitors are useful in the treatment of a variety of
allergic and inflammatory diseases including: asthma, chronic bronchitis, atopic
15 dermatitis, urticaria, allergic rhinitis, allergic conjunctivitis, vernal conjunctivitis,
eosinophilic granuloma, psoriasis, rheumatoid arthritis, septic shock, ulcerative
colitis, Crohn's disease, reperfusion injury of the myocardium and brain, chronic
glomerulonephritis, endotoxic shock and adult respiratory distress syndrome. In
addition, PDE IV inhibitors are useful in the treatment of diabetes insipidus and
20 central nervous system disorders such as depression and multi-infarct dementia.

The viruses contemplated for treatment herein are those that produce TNF as
a result of infection, or those which are sensitive to inhibition, such as by decreased
replication, directly or indirectly, by the TNF inhibitors of Formula (I) or (II). Such
viruses include, but are not limited to HIV-1, HIV-2 and HIV-3, cytomegalovirus
25 (CMV), influenza, adenovirus and the Herpes group of viruses, such as, but not
limited to, *Herpes zoster* and *Herpes simplex*.

This invention more specifically relates to a method of treating a mammal,
afflicted with a human immunodeficiency virus (HIV), which comprises
administering to such mammal an effective TNF inhibiting amount of a compound
30 of Formula (I) or (II).

The compounds of this invention may also be used in association with the
veterinary treatment of animals, other than in humans, in need of inhibition of TNF
production. TNF mediated diseases for treatment, therapeutically or
prophylactically, in animals include disease states such as those noted above, but in
35 particular viral infections. Examples of such viruses include, but are not limited to

feline immunodeficiency virus (FIV) or other retroviral infection such as equine infectious anemia virus, caprine arthritis virus, visna virus, maedi virus and other lentiviruses.

5 The compounds of this invention are also useful in treating yeast and fungal infections, where such yeast and fungi are sensitive to upregulation by TNF or will elicit TNF production *in vivo*. A preferred disease state for treatment is fungal meningitis. Additionally, the compounds of Formula (I) or (II) may be administered in conjunction with other drugs of choice for systemic yeast and fungal infections. Drugs of choice for fungal infections, include but are not limited to the
10 class of compounds called the polymixins, such as Polymycin B, the class of compounds called the imidazoles, such as clotrimazole, econazole, miconazole, and ketoconazole; the class of compounds called the triazoles, such as fluconazole, and itranazole, and the class of compound called the Amphotericins, in particular Amphotericin B and liposomal Amphotericin B.

15 The compounds of Formula (I) or (II) may also be used for inhibiting and/or reducing the toxicity of an anti-fungal, anti-bacterial or anti-viral agent by administering an effective amount of a compound of Formula (I) or (II) to a mammal in need of such treatment. Preferably, a compound of Formula (I) or (II) is administered for inhibiting or reducing the toxicity of the Amphotericin class of
20 compounds, in particular Amphotericin B.

Preferred compounds are as follows:

When R₁ for the compounds of the Formula (I) is an alkyl substituted by 1 or more halogens, the halogens are preferably fluorine and chlorine, more preferably a C₁₋₄ alkyl substituted by 1 or more fluorines. The preferred halo-
25 substituted alkyl chain length is one or two carbons, and most preferred are the moieties -CF₃, -CH₂F, -CHF₂, -CF₂CHF₂, -CH₂CF₃, and -CH₂CHF₂. Preferred R₁ substituents for the compounds of the Formula (I) are CH₂-cyclopropyl, CH₂-C₅₋₆ cycloalkyl, C₄₋₆ cycloalkyl, C₇₋₁₁ polycycloalkyl, (3- or 4-cyclopentenyl), phenyl, tetrahydrofuran-3-yl, benzyl or C₁₋₂ alkyl optionally substituted by 1 or
30 more fluorines, -(CH₂)₁₋₃C(O)O(CH₂)₀₋₂CH₃, -(CH₂)₁₋₃O(CH₂)₀₋₂CH₃, and -(CH₂)₂₋₄OH.

When the R₁ term contains the moiety (CR₄R₅), the R₄ and R₅ terms are independently hydrogen or alkyl. This allows for branching of the individual methylene units as (CR₄R₅)_n or (CR₄R₅)_m; each repeating methylene unit is
35 independent of the other, e.g., (CR₄R₅)_n wherein n is 2 can be -CH₂CH(-CH₃)-, for instance. The individual hydrogen atoms of the repeating methylene unit or the

branching hydrocarbon can optionally be substituted by fluorine independent of each other to yield, for instance, the preferred R₁ substitutions, as noted above.

When R₁ is a C₇₋₁₁ polycycloalkyl, examples are bicyclo[2.2.1]-heptyl, bicyclo[2.2.2]octyl, bicyclo[3.2.1]octyl, tricyclo[5.2.1.0^{2,6}]decyl, etc. additional
 5 examples of which are described in Saccamano *et al.*, WO 87/06576, published 5 November 1987, whose disclosure is incorporated herein by reference in its entirety.

Z is S(O)_mR₉, OS(O)₂R₉, OR₉, OC(O)NR₇R₉, OC(O)(O)_qR₇, O(CR₄R₅)_nOR₉, or NR₉R₉ in compounds of the Formula (I) and also NHR₁₄ in
 10 compounds of the Formula (II). Preferably, q is 0. Preferred Z terms are S(O)_mR₉, OS(O)₂R₉, OR₉, OC(O)NR₇R₉, O(CR₄R₅)_nOR₉, or NR₉R₉ in compounds of the Formula (I) and also NHR₁₄ in compounds of the Formula (II).

Z" in Formula (II) is preferably C(O)R₁₄, C(O)OR₁₄, C(O)NR₁₀R₁₄, C(NR₁₀)NR₁₀R₁₄, CN, C(NOR₈)R₁₄, C(NR₈)NR₁₀R₁₄, C(NCN)NR₈R₁₄, C(NCN)SR₁₁, (1-, 4- or 5-{R₁₄}-2-imidazolyl), (1-, 4- or 5-{R₁₄}-3-pyrazolyl),
 15 (1-, 2- or 5-{R₁₄}-4-triazolyl[1,2,3]), (1-, 2-, 4- or 5-{R₁₄}-3-triazolyl[1,2,4]), (1- or 2-{R₁₄}-5-tetrazolyl), (4- or 5-{R₁₄}-2-oxazolyl), (3- or 4-{R₁₄}-5-isoxazolyl), (3-{R₁₄}-5-oxadiazolyl[1,2,4]), (5-{R₁₄}-3-oxadiazolyl[1,2,4]), (5-{R₁₄}-2-oxadiazolyl[1,3,4]), (5-{R₁₄}-2-thiadiazolyl[1,3,4]), (4- or 5-{R₁₄}-2-thiazolyl), (4- or 5-{R₁₄}-2-oxazolidinyl), (4- or
 20 5-{R₁₄}-2-thiazolidinyl), (1-, 4- or 5-{R₁₄}-2-imidazolidinyl).

Preferred X groups for Formulas (I) and (II) are those wherein X is YR₂ and Y is oxygen. The preferred X₂ group Formulas (I) and (II) is that wherein X₂ is oxygen. The preferred X₃ group is hydrogen. Preferred R₂ groups, where
 25 applicable, are a C₁₋₂ alkyl optionally substituted by 1 or more halogens. The halogen atoms are preferably fluorine and chlorine, more preferably fluorine. More preferred R₂ groups are those wherein R₂ is methyl, or the fluoro-substituted alkyls, specifically a C₁₋₂ alkyl, such as a -CF₃, -CHF₂, or -CH₂CHF₂ moiety. Most preferred are the -CHF₂ and -CH₃ moieties.

Preferred R₃ moieties are C(O)NH₂, C≡CR₈, CN, C(Z')H, CH₂OH, CH₂F, CF₂H, and CF₃. Z' is preferably O or NOR₈. More preferred are C≡CH and CN.
 30

Preferred R₁₅ moieties include optionally substituted -(CH₂)₁₋₂(cyclopropyl), -(CH₂)₀₋₂(cyclobutyl), -(CH₂)₀₋₂(cyclopentyl), -(CH₂)₀₋₂(cyclohexyl), -(R₄R₅)₀₋₂(2-, 3- or 4-pyridyl), (R₄R₅)₁₋₂(2-imidazolyl), (R₄R₅)₂(4-morpholinyl), (R₄R₅)₂(4-piperazinyl), (R₄R₅)₁₋₂(2-thienyl),
 35 (R₄R₅)₁₋₂(4-thiazolyl), and (R₄R₅)₀₋₂phenyl;

Preferred rings when the two R₉ terms in the moiety NR₉R₉ together with the nitrogen to which they are attached form a 5 to 7 membered ring optionally containing at least one additional heteroatom selected from O, N or S include, but
 5 are not limited to, the morpholinyl, piperazinyl, or pyrrolyl rings.

Preferred rings when R₈ and R₁₀ in the moiety -NR₈R₁₀ together with the nitrogen to which they are attached form a 5 to 7 membered ring optionally containing at least one additional heteroatom selected from O, N, or S include, but
 10 are not limited to 1-imidazolyl, 2-(R₈)-1-imidazolyl, 1-pyrazolyl, 3-(R₈)-1-pyrazolyl, 1-triazolyl, 2-triazolyl, 5-(R₈)-1-triazolyl, 5-(R₈)-2-triazolyl, 5-(R₈)-1-tetrazolyl, 5-(R₈)-2-tetrazolyl, 1-tetrazolyl, 2-tetrazolyl, morpholinyl, piperazinyl, 4-(R₈)-1-piperazinyl, or pyrrolyl ring.

Preferred rings when R₁₀ and R₁₄ in the moiety -NR₁₀R₁₄ together with the nitrogen to which they are attached may form a 5 to 7 membered ring optionally
 15 containing at least one additional heteroatom selected from O, N, or S include, but are not limited to 1-imidazolyl, 1-pyrazolyl, 1-triazolyl, 2-triazolyl, 1-tetrazolyl, 2-tetrazolyl, morpholinyl, piperazinyl, and pyrrolyl. The respective rings may be additionally substituted, where applicable, on an available nitrogen or carbon by the moiety R₁₅ as described herein for Formula (II). Illustrations of such carbon
 20 substitutions includes, but is not limited to, 2-(R₁₅)-1-imidazolyl, 4-(R₁₅)-1-imidazolyl, 5-(R₁₅)-1-imidazolyl, 3-(R₁₅)-1-pyrazolyl, 4-(R₁₅)-1-pyrazolyl, 5-(R₁₅)-1-pyrazolyl, 4-(R₁₅)-2-triazolyl, 5-(R₁₅)-2-triazolyl, 4-(R₁₅)-1-triazolyl, 5-(R₁₅)-1-triazolyl, 5-(R₁₅)-1-tetrazolyl, and 5-(R₁₅)-2-tetrazolyl. Applicable nitrogen substitution by R₁₅ includes, but is
 25 not limited to, 1-(R₁₅)-2-tetrazolyl, 2-(R₁₅)-1-tetrazolyl, 4-(R₁₅)-1-piperazinyl. Where applicable, the ring may be substituted one or more times by R₁₅.

Preferred groups for -NR₁₀R₁₄ which contain a heterocyclic ring are 5-(R₁₄)-1-tetrazolyl, 2-(R₁₄)-1-imidazolyl, 5-(R₁₄)-2-tetrazolyl, 4-(R₁₄)-1-piperazinyl, or 4-(R₁₅)-1-piperazinyl.

30 Preferred rings for R₁₃ include (2-, 4- or 5-imidazolyl), (3-, 4- or 5-pyrazolyl), (4- or 5-triazolyl[1,2,3]), (3- or 5-triazolyl[1,2,4]), (5-tetrazolyl), (2-, 4- or 5-oxazolyl), (3-, 4- or 5-isoxazolyl), (3- or 5-oxadiazolyl[1,2,4]), (2-oxadiazolyl[1,3,4]), (2-thiadiazolyl[1,3,4]), (2-, 4-, or 5-thiazolyl), (2-, 4-, or 5-oxazolidinyl), (2-, 4-, or 5-thiazolidinyl), or (2-, 4-, or 5-imidazolidinyl).

35 When the R₁₅ group is optionally substituted by a heterocyclic ring such as imidazolyl, pyrazolyl, triazolyl, tetrazolyl, or thiazolyl, the heterocyclic ring itself may be optionally substituted by R₈ either on an available nitrogen or carbon atom,

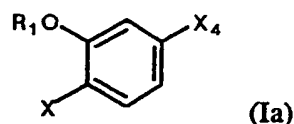
such as 1-(R₈)-2-imidazolyl, 1-(R₈)-4-imidazolyl, 1-(R₈)-5-imidazolyl, 1-(R₈)-3-pyrazolyl, 1-(R₈)-4-pyrazolyl, 1-(R₈)-5-pyrazolyl, 1-(R₈)-4-triazolyl, or 1-(R₈)-5-triazolyl. Where applicable, the ring may be substituted one or more times by R₈.

- 5 Preferred are those compounds of Formulas (I) and (II) wherein R₁ is -CH₂-cyclopropyl, -CH₂-C₅₋₆ cycloalkyl, -C₄₋₆ cycloalkyl, tetrahydrofuran-3-yl, (3- or 4-cyclopentenyl), benzyl or -C₁₋₂ alkyl optionally substituted by 1 or more fluorines, and -(CH₂)₂₋₄ OH; R₂ is methyl or fluoro-substituted alkyl, R₃ is CN or C≡CR₈; and X is YR₂.

- 10 Most preferred are those compounds wherein R₁ is -CH₂-cyclopropyl, cyclopentyl, methyl or CF₂H; R₃ is CN or C≡CH; X is YR₂; Y is oxygen; X₂ is oxygen; X₃ is hydrogen; and R₂ is CF₂H or methyl.

A preferred subgenus of the compounds of the Formula (I) is the compounds of the Formula (Ia)

15



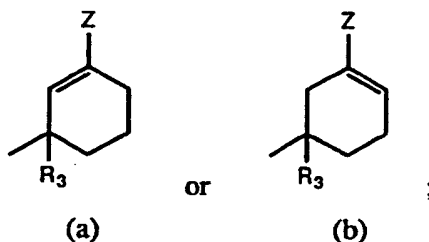
wherein:

- R₁ is CH₂-cyclopropyl, CH₂-C₅₋₆ cycloalkyl, C₄₋₆ cycloalkyl, C₇₋₁₁ polycycloalkyl, (3- or 4-cyclopentenyl), phenyl, tetrahydrofuran-3-yl, benzyl or C₁₋₂ alkyl optionally substituted by 1 or more fluorines,

- 20 -(CH₂)₁₋₃C(O)O(CH₂)₀₋₂CH₃, -(CH₂)₁₋₃O(CH₂)₀₋₂CH₃, and -(CH₂)₂₋₄OH;

X is YR₂, halogen, nitro, NR₄R₅, or formyl amine;

X₄ is



25

Y is O or S(O)_{m'};

m' is 0, 1, or 2;

R₂ is -CH₃ or -CH₂CH₃ optionally substituted by 1 or more halogens;

- 30 R₃ is hydrogen, C₁₋₄ alkyl, CH₂NHC(O)C(O)NH₂, fluoro-substituted C₁₋₄ alkyl, CN, CH₂OR₈, C(Z')H, C(O)OR₈, C(O)NR₈R₁₀, or C≡CR₈;

Z is S(O)_{m'}R₉, OS(O)₂R₉, OR₉, OC(O)NR₇R₉, OC(O)(O)_qR₇, O(CR₄R₅)_nOR₉, or NR₉R₉;

Z' is O or NOR₈;

q is 0 or 1;

R₇ is independently hydrogen or R₉;

5 R₈ is independently selected from hydrogen or C₁₋₄ alkyl optionally substituted by one to three fluorines;

R₈ is R₈ or fluorine;

10 R₉ is independently C₁₋₁₀ alkyl, C₂₋₁₀ alkenyl, C₃₋₇ cycloalkyl, C₄₋₆ cycloalkenyl, aryl, arylalkyl, heteroaryl, heteroarylalkyl, each of which may be optionally substituted by one or more fluorine atoms, or two R₉ terms appearing as NR₉R₉ may together with the nitrogen form a 5 to 7 membered ring optionally containing one or more additional heteroatoms selected from O/N/or S;

R₁₀ is OR₈ or R₈;

provided that:

f) when q is 1 in OC(O)(O)_qR₇, then R₇ is not hydrogen;

15 g) when Z' is NR₈ then R₈ is not hydrogen;

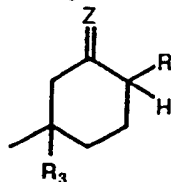
or the pharmaceutically acceptable salts thereof.

Exemplified compounds of Formula (I) are:

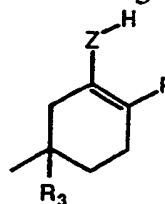
3-cyano-3-(3-cyclopentyloxy-4-methoxyphenyl)cyclohex-1-en-1-yl
20 trifluoromethylsulfonate; 5-cyano-5-(3-cyclopentyloxy-4-methoxyphenyl)cyclohex-1-en-1-yl trifluoromethylsulfonate. An exemplified compound of Formula (II) is 2-carbomethoxy-5-cyano-5-(3-cyclopentyloxy-4-methoxyphenyl)-1-(methoxymethoxy)cyclohex-1-ene.

25 It will be recognized that some of the compounds of Formula (I) and (II) may exist in both racemic and optically active forms; some may also exist in distinct diastereomeric forms possessing distinct physical and biological properties. All of these compounds are considered to be within the scope of the present invention.

Some compounds of Formula (II) may exist in a tautomeric form, such as the imine form. This may be represented by the =Z (or ylidine bond) being



- 5 exocyclic to the cyclohexane ring (or R_3) as contrasted to the endocyclic or $C(-ZH)=C(-R)-$ moiety wherein the cyclohexane ring is now



unsaturated in the 1-2 position, i.e. cyclohex-1-ene, or R_3 and R is Z" in Formula (II). It is also recognized that the 2-position of the ring in the exocyclic form can be substituted (R) such as in the compounds of Formula (II).

- 10 The term "C₁₋₃ alkyl", "C₁₋₄ alkyl", "C₁₋₆ alkyl" or "alkyl" groups includes both straight or branched chain radicals of 1 to 10, unless the chain length is limited thereto, including, but not limited to methyl, ethyl, n-propyl, isopropyl, n-butyl, sec-butyl, isobutyl, *tert*-butyl, and the like.

- 15 "Alkenyl" means both straight or branched chain radicals of 1 to 6 carbon lengths, unless the chain length is limited thereto, including but not limited to vinyl, 1-propenyl, 2-propenyl, 2-propynyl, or 3-methyl-2-propenyl.

The term "cycloalkyl" or "cycloalkyl alkyl" means groups of 3-7 carbon atoms, such as cyclopropyl, cyclopropylmethyl, cyclopentyl, or cyclohexyl.

- 20 "Aryl" or "aralkyl", unless specified otherwise, means an aromatic ring or ring system of 6-10 carbon atoms, such as phenyl, benzyl, phenethyl, or naphthyl. Preferably the aryl is monocyclic, i.e. phenyl. The alkyl chain is meant to include both straight or branched chain radicals of 1 to 4 carbon atoms.

"Heteroaryl" means an aromatic ring system containing one or more heteroatoms, such as imidazolyl, triazolyl, oxazolyl, pyridyl, pyrimidyl, pyrazolyl, pyrrolyl, furanyl, or thienyl.

- 25 "Halo" means all halogens, i.e., chloro, fluoro, bromo, or iodo.

Inhibiting the production of IL-1" or "inhibiting the production of TNF" means:

- 30 a) a decrease of excessive *in vivo* IL-1 or TNF levels, respectively, in a human to normal levels or below normal levels by inhibition of the *in vivo* release of IL-1 by all cells, including but not limited to monocytes or macrophages;

b) a down regulation, at the translational or transcriptional level, of excessive *in vivo* IL-1 or TNF levels, respectively, in a human to normal levels or below normal levels; or

c) a down regulation, by inhibition of the direct synthesis of IL-1 or TNF levels as a postranslational event.

The phrase "TNF mediated disease or disease states" means any and all disease states in which TNF plays a role, either by production of TNF itself, or by TNF causing another cytokine to be released, such as but not limited to IL-1 or IL-6. A disease state in which IL-1, for instance is a major component, and whose production or action, is exacerbated or secreted in response to TNF, would therefore be considered a disease state mediated by TNF. As TNF- β (also known as lymphotoxin) has close structural homology with TNF- α (also known as cachectin), and since each induces similar biologic responses and binds to the same cellular receptor, both TNF- α and TNF- β are inhibited by the compounds of the present invention and thus are herein referred to collectively as "TNF" unless specifically delineated otherwise. Preferably TNF- α is inhibited.

"Cytokine" means any secreted polypeptide that affects the functions of cells, and is a molecule which modulates interactions between cells in immune, inflammatory, or hematopoietic responses. A cytokine includes, but is not limited to, monokines and lymphokines regardless of which cells produce them. The cytokine inhibited by the present invention for use in the treatment of a HIV-infected human must be a cytokine which is implicated in (a) the initiation and/or maintenance of T cell activation and/or activated T cell-mediated HIV gene expression and/or replication, and/or (b) any cytokine-mediated disease associated problem such as cachexia or muscle degeneration. Preferably, his cytokine is TNF- α .

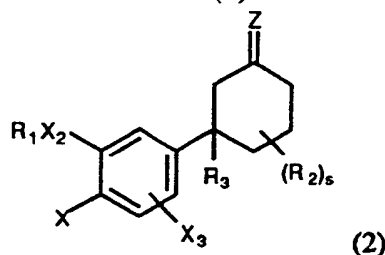
All of the compounds of Formulas (I) and (II) are useful in the method of inhibiting the production of TNF, preferably by macrophages, monocytes or macrophages and monocytes, in a mammal, including humans, in need thereof. All of the compounds of Formulas (I) and (II) are useful in the method of inhibiting or mediating the enzymatic or catalytic activity of PDE IV and in treatment of disease states mediated thereby.

METHODS OF PREPARATION

Preparation of the compounds of the Formula (I) can be carried out by one of skill in the art according to the procedures outlined in the Examples, *infra*. The

preparation of any remaining compounds of the Formula (I) not described therein may be prepared by the analogous processes disclosed herein which comprise:

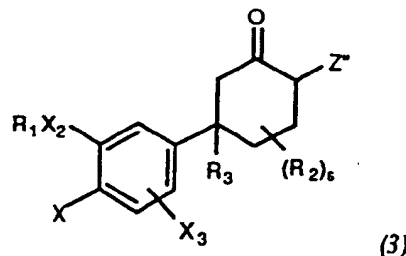
a) reacting a compound of the Formula (2)



- 5 wherein R₁ represents R₁ as defined in relation to Formula (I) or a group convertible to R₁ and X, X₂ and X₃ represent X, X₂ and X₃ as defined in relation to Formula (I) or a group convertible to X, X₂ or X₃ and R₂ and R₃ represent R₂ and R₃ as defined in relation to Formula (I) or a group convertible to R₂ or R₃ and wherein X or X₃ is other than Br, I, NO₂, amino, or S(O)_mR₂ when m' is 0, 1
 10 or 2, with a suitable base in a suitable non-reacting solvent followed by reaction with a suitable alkylating or acylating agent [LS(O)₂R₉, LR₉, L(CR₄R₅)_nOR₉, LC(O)(O)_qR₇, or LC(O)NR₇R₉, wherein L is a leaving group] to provide compounds of the Formula (I) wherein Z is OS(O)₂R₉, OR₉, O(CR₄R₅)_nOR₉, OC(O)(O)_qR₇, or OC(O)NR₇R₇ and R₃ is other than C(=Z')H; preparation of such
 15 compounds of Formula (I) wherein R₃ is C(=Z')H proceeds in an analogous fashion from the compound of Formula (2) wherein =Z' is an aldehyde protecting group, such as a dimethylacetal or a dioxolane, followed by deprotection to the aldehyde and subsequent elaboration by standard procedures known to those of skill in the art to the remaining compounds of Formula (I) wherein Z' is other than O.
- 20 b) preparation of compounds of the Formula (I) wherein Z is NR₉R₉ or SR₉ proceeds by reacting a compound of the Formula (2) with an appropriate amine of the formula HNR₉R₉ or an appropriate thiol of the formula HSR₉ in the presence of a suitable acidic or basic catalyst with scavenging or removal of water. Alternatively, such compounds may be obtained by treatment of an appropriate
 25 compound of the Formula (I) wherein Z is OS(O)₂R₉, OR₉, or O(CR₄R₅)_nOR₉ and R₃ is other than C(=Z')H with an appropriate amine of the formula HNR₉R₉ or an appropriate thiol of the formula HSR₉ in an aprotic solvent; preparation of such compounds of Formula (I) wherein R₃ is C(=Z')H proceeds in an analogous fashion from the compound of Formula (2) wherein =Z' is an aldehyde protecting group,
 30 such as a dimethylacetal or a dioxolane, followed by deprotection to the aldehyde and subsequent elaboration by standard procedures known to those of skill in the art to the remaining compounds of Formula (I) wherein Z' is other than O.

Compounds of the Formula (2) may be prepared in turn by the processes described in the application filed on even date herewith and identified as P50109.

- 5 Some compounds of the Formula (II) may be prepared by processes analogous to those above by reacting the appropriate reagent with a compound of the Formula (3)



10

- wherein R_1 represents R_1 as defined in relation to Formula (I) or a group convertible to R_1 and X , X_2 and X_3 represent X , X_2 and X_3 as defined in relation to Formula (I) or a group convertible to X , X_2 or X_3 and R_3 represents R_3 as defined in relation to Formula (I) or a group convertible to R_3 and Z'' represents Z'' as defined in relation to Formula (I) or a group convertible to Z'' .

- 15 Compounds of the Formula (3) may be prepared in turn by the processes described in the application filed on even date herewith and identified as P50197.

- Some compounds of Formula (II) may be prepared from other compounds of the Formula (II) by, e.g., functional group manipulation of the Z'' group either preceding functional group manipulation of the Z group or, in some cases, with appropriate protection and deprotection of chemically sensitive Z group functionality during functional group manipulation of the Z'' group. Some such manipulations of the Z'' group may be accomplished by the processes described in U.S. application serial number 862,030 filed 2 April 1992 and its corresponding continuation-in-part application USSN 968,762 filed 30 October 1992.

- 25 With proper manipulation (protection/deprotection) of any chemically sensitive functional groups:

- a) Compounds of the Formula (I) wherein X or X_3 are formyl amine may be formed at the last step, by formylating a compound wherein X or X_3 is NH_2 , obtained by removal of a protecting group from the amine functionality; such protective groups are well known to those skilled in the art, See Greene, T. and

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Wuts, P.G.M., Protecting Groups in Organic Synthesis, 2nd Ed., John Wiley and Sons, New York (1991).

b) Compounds of the Formula (I) wherein X or X₃ are Br, I or SR₂ may be prepared from a similarly deprotected amine by diazotization of the amine and diazonium displacement.

c) Compounds of the Formula (I) wherein X or X₃ are NO₂ may be prepared from a similarly deprotected amine by oxidation of the amine to the nitro group.

d) Compounds of the Formula (I) wherein Y is S(O)^{m'} when m' is 0, 1 or 2 may be prepared from the compounds of the Formula (I) wherein Y is S by oxidation of the SR₂ moiety under conditions well known those skilled in the art

The following examples are set out to illustrate how to make the compounds of this invention and methods for determining associated therapeutic activity. These examples are not intended to limit the invention in any manner, their purpose is illustrative rather than limiting.

SYNTHETIC EXAMPLES

EXAMPLE 1

Preparation of 3-cyano-3-(3-cyclopentyloxy-4-methoxyphenyl)cyclohex-1-en-1-yl trifluoromethylsulfonate and 5-cyano-5-(3-cyclopentyloxy-4-methoxyphenyl)cyclohex-1-en-1-yl trifluoromethylsulfonate

To a solution of 2,2,6,6-tetramethylpiperidine (9.0 milliliters (hereinafter mL), 53.2 millimoles (hereinafter mmol)) in tetrahydrofuran (150 mL) at 0°C under an argon atmosphere was added dropwise over 0.5 hours (hereinafter h) n-butyllithium (23.5 mL of 2.25M solution, 53.2 mmol), the resulting solution was stirred for 30 minutes (hereinafter min) and then was cooled to -78°C. To this was added dropwise over 75 min a solution of 3-cyano-3-(3-cyclopentyloxy-4-methoxyphenyl)cyclohexan-1-one (15.14 grams (hereinafter g), 48.3 mmol) in tetrahydrofuran (125 mL). The resulting mixture was stirred at -78°C for 1.5h, at which time N-phenyl-trifluoromethylsulfonimide (16.9 g, 44.9 mmol) was added. The mixture was allowed to warm slowly to room temperature and after 2h, the mixture was poured into water and extracted three times with methylene chloride. The organic extract was dried (magnesium sulfate) and concentrated under reduced pressure. The residue was purified by flash chromatography, eluting with 9:1 hexanes/ethyl acetate, to afford an oil (17.82 g, 90%) as a mixture of double bond isomers.

¹H-NMR (400 MHz, CDCl₃) δ 6.98 (m, 2H), 6.89 (m, 1H), 6.00 (br, 0.67H), 5.92 (s, 0.33H), 3.86 (s, 2H), 3.85 (s, 1H), 2.86 (br, 1.33H), 2.70 (m, 0.67H), 2.46 (m, 1.33H), 2.35 (m, 0.33H), 2.23 (m, 0.67H), 1.8 - 2.0 (m, 9.33H), 1.6 (m, 2H) ppm

EXAMPLE 2

Preparation of 2-carbomethoxy-5-cyano-5-(3-cyclopentyloxy-4-methoxyphenyl)-1-(trifluoromethylsulfonato)cyclohex-1-ene

To a solution of 2,6-di-tert-butyl-4-methylpyridine (10.3 grams, 50.2 millimoles) and trifluoromethanesulfonic anhydride (7.07 milliliters, 41.8 mmol) in dichloromethane (165 mL) at room temperature under an argon atmosphere is added over 0.5 hours a solution of 2-carbomethoxy-5-cyano-5-(3-cyclopentyloxy-4-methoxyphenyl)cyclohexan-1-one (12.5 g, 33.6 mmol) in dichloromethane (160 mL). The resulting mixture is stirred overnight and then is concentrated to half-volume. Ether is added, the salt is removed by filtration and the filtrate is concentrated *in vacuo*. Purification by flash chromatography, eluting with 3:1 hexanes/ethyl acetate, affords the product.

METHODS OF TREATMENT

In order to use a compound of Formula (I) or (II) or a pharmaceutically acceptable salt thereof for the treatment of humans and other mammals, it is normally formulated in accordance with standard pharmaceutical practice as a pharmaceutical composition.

The compounds of Formula (I) or (II), or a pharmaceutically acceptable salt thereof can be used in the manufacture of a medicament for the prophylactic or therapeutic treatment of any disease state in a human or other mammal which is mediated by inhibition of PDE IV, such as but not limited to asthma, allergic, or inflammatory diseases. The compounds of Formula (I) or (II) are administered in an amount sufficient to treat such a disease in a human or other mammal.

For the purposes herein all methods of treatment and dosage regimens apply equally to both the compounds of Formula (I) or (II).

In order to use a compound of Formula (I) or (II), or a pharmaceutically acceptable salt thereof, for the treatment of humans and other mammals it is normally formulated in accordance with standard pharmaceutical practice as a pharmaceutical composition.

The amount of a compound of Formula (I) or (II) required for therapeutic effect on topical administration will, of course, vary with the compound chosen, the nature and severity of the condition and the animal undergoing treatment, and is

ultimately at the discretion of the physician.

The daily dosage regimen for oral administration is suitably about .001 mg/kg to 100mg/kg, preferably 0.01 mg/Kg to 40 mg/Kg, of a compound of Formula (I) or (II) or a pharmaceutically acceptable salt thereof calculated as the free acid or base, which ever is appropriate. The active ingredient may be administered from 1 to 6 times a day, sufficient to exhibit activity.

No unacceptable toxic effects are expected when these compounds are administered in accordance with the present invention.

UTILITY EXAMPLES

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EXAMPLE A

Inhibitory effect of compounds of the compounds of this invention on *in vitro* TNF production by human monocytes

The inhibitory effect of compounds of Formula (I) or (II) on *in vitro* TNF production by human monocytes may be determined by the protocol as described in Badger *et al.*, EPO published Application 0 411 754 A2, February 6, 1991, and in Hanna, WO 90/15534, December 27, 1990.

EXAMPLE B

Two models of endotoxic shock have been utilized to determine *in vivo* TNF activity for the compounds of this invention. The protocol used in these models is described in Badger *et al.*, EPO published Application 0 411 754 A2, February 6, 1991, and in Hanna, WO 90/15534, December 27, 1990.

The compound of Example 1 herein demonstrated a positive *in vivo* response in reducing serum levels of TNF induced by the injection of endotoxin.

EXAMPLE C

25

Isolation of PDE Isozymes

The phosphodiesterase inhibitory activity and selectivity of the compounds of of this invention.s can be determined using a battery of five distinct PDE isozymes. The tissues used as sources of the different isozymes are as follows: 1) PDE Ib, porcine aorta; 2) PDE Ic, guinea-pig heart; 3) PDE III, guinea-pig heart; 4) PDE IV, human monocyte; and 5) PDE V (also called "Ia"), canine trachealis. PDEs Ia, Ib, Ic and III are partially purified using standard chromatographic techniques [Torphy and Cieslinski, Mol. Pharmacol., 37:206-214, 1990]. PDE IV is purified to kinetic homogeneity by the sequential use of anion-exchange followed by heparin-Sepharose chromatography [Torphy *et al.*, J. Biol. Chem., 267:1798-1804, 1992].

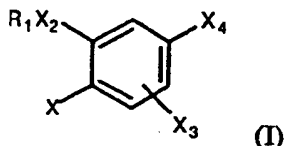
Phosphodiesterase activity is assayed as described in the protocol of Torphy and Cieslinski, Mol. Pharmacol., 37:206-214, 1990. Positive IC₅₀'s in the nanomolar to μ M range for compounds of the workings examples described herein
5 for compounds of this invention have been demonstrated.

EXAMPLE D

The ability of selected PDE IV inhibitors to increase cAMP accumulation in intact tissues is assessed using U-937 cells, a human monocyte cell line that has been shown to contain a large amount of PDE IV. To assess the activity of PDE IV
10 inhibition in intact cells, nondifferentiated U-937 cells (approximately 10^5 cells/reaction tube) were incubated with various concentrations (0.01-1000 μ M) of PDE inhibitors for one minute and 1 μ M prostaglandin E2 for an additional four minutes. Five minutes after initiating the reaction, cells were lysed by the addition
15 of 17.5% perchloric acid, the pH was neutralized by the addition of 1M potassium carbonate and cAMP content was assessed by RIA. A general protocol for this assay is described in Brooker *et al.*, Radioimmunassay of cyclic AMP and cyclic GMP., Adv. Cyclic Nucleotide Res., 10:1-33, 1979. The compounds of the working examples as described herein for compounds of this invention have demonstrated a positive EC₅₀s in the μ M range in the above assay.

What is claimed is:

1. A compound of formula (I):



wherein:

R_1 is $-(CR_4R_5)_n C(O)O(CR_4R_5)_m R_6$, $-(CR_4R_5)_n C(O)NR_4(CR_4R_5)_m R_6$, $-(CR_4R_5)_n O(CR_4R_5)_m R_6$, or $-(CR_4R_5)_r R_6$ wherein the alkyl moieties may be optionally substituted with one or more halogens;

m is 0 to 2;

n is 1 to 4;

r is 0 to 6;

R_4 and R_5 are independently selected from hydrogen or a C_{1-2} alkyl;

R_6 is hydrogen, methyl, hydroxyl, aryl, halo substituted aryl, aryloxy C_{1-3} alkyl, halo substituted aryloxy C_{1-3} alkyl, indanyl, indenyl, C_{7-11} polycycloalkyl, tetrahydrofuranyl, furanyl, tetrahydropyranyl, pyranal, tetrahydrothienyl, thienyl, tetrahydrothiopyranal, thiopyranal, C_{3-6} cycloalkyl, or a C_{4-6} cycloalkyl containing one or two unsaturated bonds, wherein the cycloalkyl and heterocyclic moieties may be optionally substituted by 1 to 3 methyl groups or one ethyl group;

provided that:

a) when R_6 is hydroxyl, then m is 2; or

b) when R_6 is hydroxyl, then r is 2 to 6; or

c) when R_6 is 2-tetrahydropyranyl, 2-tetrahydrothiopyranal, 2-tetrahydrofuranyl, or 2-tetrahydrothienyl, then m is 1 or 2; or

d) when R_6 is 2-tetrahydropyranyl, 2-tetrahydrothiopyranal, 2-tetrahydrofuranyl, or 2-tetrahydrothienyl, then r is 1 to 6;

e) when n is 1 and m is 0, then R_6 is other than H in $-(CR_4R_5)_n O(CR_4R_5)_m R_6$;

X is YR_2 , halogen, nitro, NR_4R_5 , or formyl amine;

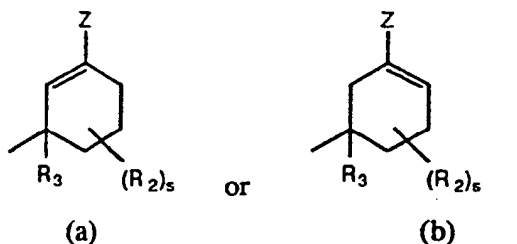
Y is O or $S(O)_{m'}$;

m' is 0, 1, or 2;

X_2 is O or NR_8 ;

X_3 is hydrogen or X;

X_4 is



R_2 is independently selected from $-CH_3$ or $-CH_2CH_3$ optionally substituted by 1 or more halogens;

5 s is 0 to 4;

R_3 is C_{1-4} alkyl, fluoro-substituted C_{1-4} alkyl, $CH_2NHC(O)C(O)NH_2$, $-CH=CR_8R_8'$, cyclopropyl optionally substituted by R_8' , CN, CH_2OR_8 , $CH_2NR_8R_{10}$, $C(Z')H$, $C(O)OR_8$, $C(O)NR_8R_{10}$, or $C=CR_8$;

Z is $S(O)_mR_9$, $OS(O)_2R_9$, OR_9 , $OC(O)NR_7R_9$, $OC(O)(O)_qR_7$,
10 $O(CR_4R_5)_nOR_9$, or NR_9R_9 ;

Z' is O, NR_8 , NNR_8R_8 , NOR_8 , NCN , $C(-CN)_2$, CR_8CN , CR_8NO_2 , $CR_8C(O)OR_8$, $CR_8C(O)NR_8R_8$, $C(-CN)NO_2$, $C(-CN)C(O)OR_9$, or $C(-CN)C(O)NR_8R_8$;

q is 0 or 1;

15 R_7 is independently hydrogen or R_9 ; R_8 is independently selected from hydrogen or C_{1-4} alkyl optionally substituted by one to three fluorines, or when R_8 and R_{10} are as $-NR_8R_{10}$ they may together with the nitrogen form a 5 to 7 membered ring optionally containing one or more additional heteroatom selected from O, N, or S;

20 R_8' is R_8 or fluorine;

R_9 is independently C_{1-10} alkyl, C_{2-10} alkenyl, C_{3-7} cycloalkyl, C_{4-6} cycloalkenyl, aryl, arylalkyl, heteroaryl, heteroarylalkyl, each of which may be optionally substituted by one or more fluorine atoms, or two R_9 terms appearing as NR_9R_9 may together with the nitrogen form a 5 to 7 membered ring optionally
25 containing one or more additional heteroatoms selected from O, N, or S;

R_{10} is OR_8 or R_8 ;

provided that:

f) when q is 1 in $OC(O)(O)_qR_7$, then R_7 is not hydrogen;

g) when Z' is NR_8 , then R_8 is not hydrogen;

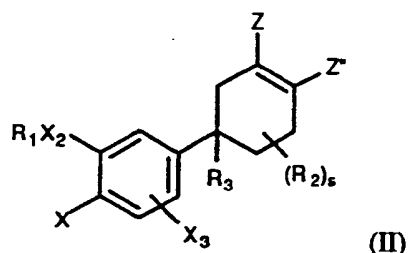
30 or the pharmaceutically acceptable salts thereof.

2. A compound of claim 1 which is

3-cyano-3-(3-cyclopentyloxy-4-methoxyphenyl)cyclohex-1-en-1-yl
trifluoromethylsulfonate; or 5-cyano-5-(3-cyclopentyloxy-4-

methoxyphenyl)cyclohex-1-en-1-yl trifluoromethylsulfonate.

3. A compound of formula (II)



5 wherein:

R_1 is $-(CR_4R_5)_nC(O)O(CR_4R_5)_mR_6$, $-(CR_4R_5)_nC(O)NR_4(CR_4R_5)_mR_6$, $-(CR_4R_5)_nO(CR_4R_5)_mR_6$, or $-(CR_4R_5)_rR_6$ wherein the alkyl moieties may be optionally substituted with one or more halogens;

m is 0 to 2;

10 n is 1 to 4;

r is 0 to 6;

R_4 and R_5 are independently selected from hydrogen or a C_{1-2} alkyl;

R_6 is hydrogen, methyl, hydroxyl, aryl, halo substituted aryl, aryloxy C_{1-3} alkyl, halo substituted aryloxy C_{1-3} alkyl, indanyl, indenyl, C_{7-11} polycycloalkyl, tetrahydrofuranyl, furanyl, tetrahydropyranyl, pyranal, tetrahydrothienyl, thienyl, tetrahydrothiopyranyl, thiopyranyl, C_{3-6} cycloalkyl, or a C_{4-6} cycloalkyl containing one or two unsaturated bonds, wherein the cycloalkyl and heterocyclic moieties may be optionally substituted by 1 to 3 methyl groups or one ethyl group;

provided that:

20 a) when R_6 is hydroxyl, then m is 2; or

b) when R_6 is hydroxyl, then r is 2 to 6; or

c) when R_6 is 2-tetrahydropyranyl, 2-tetrahydrothiopyranyl, 2-tetrahydrofuranyl, or 2-tetrahydrothienyl, then m is 1 or 2; or

d) when R_6 is 2-tetrahydropyranyl, 2-tetrahydrothiopyranyl, 2-tetrahydrofuranyl, or 2-tetrahydrothienyl, then r is 1 to 6;

e) when n is 1 and m is 0, then R_6 is other than H in $-(CR_4R_5)_nO(CR_4R_5)_mR_6$;

X is YR_2 , halogen, nitro, NR_4R_5 , or formyl amine;

Y is O or $S(O)_{m'}$;

30 m' is 0, 1, or 2;

X_2 is O or NR_8 ;

X_3 is hydrogen or X;

R₂ is independently selected from -CH₃ or -CH₂CH₃ optionally substituted by 1 or more halogens;

s is 0 to 4;

- 5 R₃ is C₁₋₄ alkyl, fluoro-substituted C₁₋₄ alkyl, CH₂NHC(O)C(O)NH₂, -CH=CR₈R₈', cyclopropyl optionally substituted by R₈', CN, CH₂OR₈, CH₂NR₈R₁₀, C(Z')H, C(O)OR₈, C(O)NR₈R₁₀, or C≡CR₈';

Z is NHR₁₄, S(O)_mR₉, OS(O)₂R₉, OR₉, OC(O)NR₇R₉, OC(O)(O)_qR₇, O(CR₄R₅)_nOR₉, or NR₉R₉;

- 10 Z' is C(Y')R₁₄, C(O)OR₁₄, C(Y')NR₁₀R₁₄, C(NR₁₀)NR₁₀R₁₄, CN, C(NOR₈)R₁₄, C(NOR₁₄)R₈, C(NR₈)NR₁₀R₁₄, C(NR₁₄)NR₈R₈, C(NCN)NR₁₀R₁₄, C(NCN)SR₁₁, (2-, 4- or 5-imidazolyl), (3-, 4- or 5-pyrazolyl), (4- or 5-triazolyl[1,2,3]), (3- or 5-triazolyl[1,2,4]), (5-tetrazolyl), (2-, 4- or 5-oxazolyl), (3-, 4- or 5-isoxazolyl), (3- or 5-oxadiazolyl[1,2,4]), (2-oxadiazolyl[1,3,4]), (2-thiadiazolyl[1,3,4]), (2-, 4-, or 5-thiazolyl), (2-, 4-, or 5-oxazolidinyl), (2-, 4-, or 5-thiazolidinyl), or (2-, 4-, or 5-imidazolidinyl); wherein
15 all of the heterocyclic ring systems may be optionally substituted one or more times by R₁₄;

Y' is O or S;

- 20 R₁₁ is C₁₋₄ alkyl optionally substituted by one to three fluorines; R₁₂ is C₃₋₇ cycloalkyl, (2-, 3- or 4-pyridyl), pyrimidyl, pyrazolyl, (1- or 2-imidazolyl), thiazolyl, triazolyl, pyrrolyl, piperaziny, piperidinyl, morpholinyl, furanyl, (2- or 3-thienyl), (4- or 5-thiazolyl), quinolinyl, naphthyl, or phenyl;

- R₁₃ is oxazolidinyl, oxazolyl, thiazolyl, pyrazolyl, triazolyl, tetrazolyl, imidazolyl, imidazolidinyl, thiazolidinyl, isoxazolyl, oxadiazolyl, or thiadiazolyl,
25 and each of these heterocyclic rings is connected through a carbon atom and each may be unsubstituted or substituted by one or two C₁₋₂ alkyl groups;

R₁₄ is hydrogen or R₁₅; or when R₁₀ and R₁₄ are as NR₁₀R₁₄ they may together with the nitrogen form a 5 to 7 membered ring optionally containing one or more additional heteroatoms selected from O/N/or S;

- 30 R₁₅ is -(CR₄R₅)_tR₁₂ or C₁₋₆ alkyl wherein the R₁₂ or C₁₋₆ alkyl group is optionally substituted one or more times by C₁₋₂ alkyl optionally substituted by one to three fluorines, -F, -Br, -Cl, -NO₂, -Si(R₄)₂, -NR₈R₁₀, -C(O)R₈, -C(O)OR₈, -OR₈, -CN, -C(O)NR₈R₁₀, -OC(O)NR₈R₁₀, -OC(O)R₈, -NR₁₀C(O)NR₈R₁₀, -NR₁₀C(O)R₈, -NR₁₀C(O)OR₉, -NR₁₀C(O)R₁₃, -C(NR₁₀)NR₈R₁₀,
35 -C(NCN)NR₈R₁₀, -C(NCN)SR₁₁, -NR₁₀C(NCN)SR₁₁, -NR₁₀C(NCN)NR₁₀R₈, -NR₁₀S(O)₂R₉, -S(O)_mR₁₁, -NR₁₀C(O)C(O)NR₈R₁₀, -NR₁₀C(O)C(O)R₁₀, thiazolyl, imidazolyl, oxazolyl, pyrazolyl, triazolyl, or tetrazolyl;

t is 0, 1, or 2;

provided that when R₁₂ is N-pyrazolyl, N-imidazolyl, N-triazolyl, N-pyrrolyl, N-piperazinyl, N-piperidinyl, or N-morpholinyl, then q is not 1;

or a pharmaceutically acceptable salts thereof.

5

4. A compound of claim 3 which is

2-carbomethoxy-5-cyano-5-(3-cyclopentyloxy-4-methoxyphenyl)-1-(methoxymethyloxy)cyclohex-1-ene.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/10817**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) :C07C 255/46

US CL :558/426

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 558/426

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
CAS ONLINE**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Chemical Abstracts, Vol 115, issued 1991, Solomina et al, "Synthesis of 6,7-dimethoxy-2-methyl-4,4'-spiro-1'-(3-amino-2-hydroxypropoxy)cyclohexane-1,2,3,4-tetrahydroisoquinolines and their biological activity," see abstract no. 8542s.	1-4
T	Chemical Abstracts, vol. 120, issued 1994, Christensen et al, "Preparation of arylcyclohexanes useful for inhibiting production of tumor necrosis factor," see abstract no. 163532k.	1-4
T	Chemical Abstracts, vol. 120, issued 1994, Christensen et al, "Cyclohexylbenzones useful for treating allergic or inflammatory diseases," see abstract no. 191326q.	1-4

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"G" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

18 JANUARY 1995

Date of mailing of the international search report

JAN 31 1995

Name and mailing address of the ISA/US
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Telephone No. (703) 308-1235

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/10817

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 1 AND 3
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

Please See Extra Sheet.

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US94/10817

BOX 1. OBSERVATIONS WHERE CLAIMS WERE FOUND UNSEARCHABLE

2. Where no meaningful search could be carried out, specifically:

Aside from the specific structures of page 11, lines 24-27; page 15, lines 26-28; page 16, lines 7-8; the two compounds of claim 2 and the compound of claim 4, i.e., compounds with clearly defined structures, the terms used in the unsearchable claims cannot be ascertained into meaningful enough specific compound structures such as to afford a determination of proper specific subclasses to search. Thus, the unsearchable claims will be searched only to the extent they read on searchable features (the above compounds) in the description and claims.

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